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Advanced Sensor Exploitation

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SUMMARY

This paper describes the Advanced Sensor Exploitation Testbed developed by the Rome Air Development Center for the purpose of evaluating and testing advanced techniques in the area of multi-sensor, multi-discipline correlation. The Testbed consists of three subsystems: 1) the scenario generation subsystem, 2) the sensor simulation subsystem, and 3) the correlation and exploitation algorithms. The scenario generation subsystem, referred to as Dynamic Ground Target Simulator, is a computer automated system for the development of "ground truth". Ground truth is any activity that occurs in the battlefield in relation to movement or emission of opposing ground forces. The sensor simulation subsystem consists of generic moving target indicator, radio detection/location, radar detection/location and imaging type sensors that act as filters for the ground truth. Ground truth data is filtered out (undetected) depending on local terrain and sensor operating characteristics. The correlation and exploitation algorithms are resident within the Advanced Sensor Exploitation Element and provide such data as military unit identification, the identification and tracking of high priority/critical targets, threat alerts and activity level indications. The Advanced Sensor Exploitation Testbed along with built-in evaluation routines allow for the development, test and evaluation of automated correlation and identification algorithms in as a realistic environment as possible.

ASE TESTBED

The ability to strike mobile second echelon ground forces before they can take advantage of any breakthroughs created by the first echelon is a paramount objective of the Air Force in a limited tactical environment. Limited air resources must be applied most effectively against the large number of possible targets. Due to the dynamics of the tactical battlefield the assessment, decision and deployment of these resources must be accomplished in a timely fashion. The requirement by the tactical decision makers to have accurate, up-to-date, and continuous data on the position and status of the opposing ground forces has precipitated the development of high-volume advanced sensor systems. These sensor systems have been designed to exploit a specific target characteristic such as movement or emissions and provide a high volume of information in near-real-time.

The sensor data, once correlated and fused, will be integral to a data base that can be exploited by target and threat identification and tracking algorithms in order to provide the necessary information required by tactical decision makers. The dynamic value of the sensor data, the timely requirement for information and the volume of data to be processed predicates that automatic correlation and exploitation functions be utilized.

The Advanced Sensor Exploitation (ASE) Testbed was developed by the Rome Air Development Center (RADC) to test and evaluate the advanced capabilities in automatic correlation, processing and display of the products of the advanced sensor systems such as the Moving Target Indicator, Imaging, Radio and Radar Detection type sensors. Functions which have been developed and demonstrated include: the ability to correlate data from multiple sources and multiple sensor disciplines, the ability to continuously track high priority targets, the ability to specifically identify critical nodes, the ability to automatically issue threat alerts when friendly air missions are potentially threatened by enemy Air Defense Units, and the ability to cue sensors to change modes or to observe specific areas or signals of interest. Also developed was an evaluation module to determine the accuracy and effectiveness of the ASE algorithms and a test environment that consists of a scenario generation system called the Dynamic Ground Target Simulator (DGTS) and the appropriate sensor models.

SCENARIO GENERATION

Due to the complexity and time requirements involved in the preparation of scenario data it was decided early in the ASE program to develop a modular, flexible scenario generation tool that would provide simulated ground target movement, communication and air defense activity of an opposing force. This automated scenario generator, referred to as Dynamic Ground Target Simulator, (DGTS), permits a variety of scenarios for testing purposes with minimum preparation time.

DGTS is composed of two main elements. A model construction subsystem, which provides automated tools and a methodology for the model building process, and a scenario generation subsystem which schedules and executes the events included within the models and allows interaction with the scenario to add additional events or change existing events.

The most important features of the model construction subsystem are the model definition language, which is based on PASCAL, and the model librarian. This definition language forces a structured approach to the model building process. It also encourages modular development of models which is an important consideration whenever new models must be constructed. Appropriate modules from previously developed models may be utilized and the system capabilities continue to grow with the development of each new module. The model construction subsystem also contains a librarian function which allows modules to be inserted, removed or replaced, while ensuring the necessary links to other modules within a given model are maintained. In addition to developing the model definition language, it was necessary to develop a translator for the language. This capability was provided by modifying a PASCAL compiler.

The scenario generation subsystem contains two components: a scenario executive which performs the bookkeeping function for the system, and a scenario monitor which allows a man-machine interface. The scenario executive schedules and executes events starting with initial orders received from a text editor. This process begins after the model has been constructed. The executive interacts with the model file to produce a scenario file based on the events listed in the model file. It also interacts with the scenario monitor. The scenario monitor permits interaction with the scenario through a graphic display. Events can be added or modified through the scenario monitor. Three options are provided to allow events to be added at any point in the scenario: events may be added and scheduled to begin immediately or they may be scheduled to begin in some specified length of time or they may be scheduled to begin at some specific time in the scenario.

Scenarios have been developed from the Motorized Rifle Regiment to the Combined Arms Army level operating within a 200km x 200km area based around the Fulda Gap region of Germany. Activities reflect the hierarchical nature of the military unit as well as military doctrine. Deterministic unit movement, vehicle movement, communications activity and air defense activity are contained within the models. In addition, there is probabilistic communication and air defense activity incorporated. Physical realities such as cartographic features, terrain, weather and their effects have been included.

The Dynamic Ground Target Simulator has been implemented on Digital Equipment Corporation's VAX 11/785 utilizing a RAMTEK display system for all user interactions and graphic displays. The DGTS system provides an event driven, deterministic simulation approach. A variety of scenarios can be generated utilizing the system simply by varying initial order conditions, entity data or via on-line interactive event scheduling. Scenarios are recorded for future playback and all generated scenario data can be viewed on the RAMTEK graphic display system.

SENSOR SIMULATION

Sensor simulation became a requirement for the ASE Testbed due to the unavailability of sensor output data. Also, a need arose to be able to generate sensor data utilizing varying operating characteristics in order to fully test the exploitation functions.

The sensor simulation portion of the ASE test environment consists of three subcomponents: 1) the sensors, 2) the platforms, to the extent that sensor performance is altered by a characteristic such as altitude or flight path, and 3) the information content of the output of a sensor ground processing station. The test environment currently includes generic models of an MTI sensor, a radio detection/location sensor, a radar detection/location sensor and an imaging sensor.

Ground truth information which has been generated utilizing the DGTS system is sent to the sensor systems. Based on the sensor and sensor platform characteristics as well as environmental factors such as terrain and weather at the time, a determination is made as to whether or not a detection has been made by the sensor. If it is determined that a detection has been made, messages are sent from the ground processing station to the correlation and fusion functions regarding the detections. Errors are introduced into the system at each step of the information flow process to maintain as much realism as possible.

The sensor simulation package has been implemented on a VAX 11/785 utilizing FORTRAN as the programming language. It should be noted that the sensors are simulated only to the degree required to provide realistic data to the correlation and fusion algorithms and do not consist of any full scale simulations or complex calculations.

EVALUATION

The evaluation subsystem of the ASE Testbed consists of two phases: on-line evaluation and post-experiment evaluation. On-line Evaluation is a set of software and procedures which is modifiable either at time of experiment initialization or during the course of an experiment. The statistics gathered as a result of this data gathering process can be displayed continuously or as required. This permits judgements to be made as to whether the experiment is proceeding properly and whether the proper data is being gathered. If not, modifications can be made as the experiment progresses.

The Post-Experiment Evaluation process includes the software necessary to collect the data which was archived during the On-Line Evaluation phase and to massage the data so that post-experiment analysis can be done. Post-Experiment evaluation also utilizes the ground truth file created by DGTS and other files which were accessed during the experiment. Products created by the Post-Experiment Evaluation process include a trace of all functions utilized, a trace report of any products produced by any of the algorithms, a list of any "ground truth events" not detected by the sensors, and a data base activity report.

ASE ELEMENT

The ASE Element is the segment of the ASE Testbed where all of the multi-sensor exploitation functions are implemented. The ASE Element software performs rapid correlation of information obtained from both the advanced, near-real-time, high volume sensor systems and intelligence information sources and utilizes the resulting correlated data base to locate areas of high ground activity, identify military units, maintain a continuous observation of high priority targets, and identify threats to friendly air missions. These tasks are performed by the invocation of six functions; correlation, wide area surveillance, military unit analysis, special target analysis, dynamic situation assessment and automatic threat analysis. Support files such as cartographic and terrain data files, radar and radio characteristic files and unit templating files are utilized by the six functions.

CORRELATION

The ability to fuse the multi-sensor data and display it in a comprehensible format to the user fundamentally depends on the correlation or "association" of the sensor reports to each other. Correlation accepts the sensor reports from all of the sensor types and a C^3I source and integrates these reports into a single data base that is utilized by the other functions to develop a dynamic representation of the battlefield. The data in the correlated data base is stored as either an entity or group. An entity is a radio or radar and a group is made up of several vehicles and may have one or more entities associated with it. New reports are associated with existing data by utilizing radio and radar detection reports for entity to entity and entity to group associations and the MTI, Imaging, and C^3I reports for group to group associations.

When either a radio or radar detection report is received, the confidence level of the sensor target ID is checked. If a high confidence level is indicated, the association file is searched to find an entity previously linked to that sensor target ID. If an entity is found, the association file is updated. Otherwise, a new entity is added to the association file. If the confidence level of the sensor target ID is low, then a measurement of association (MOA) is calculated. The MOA is a formula that weights various attributes such as frequency, position, and pulse repetition interval by their reliability. The MOA is calculated by first filtering out entities that are of a different type or are operating at a different frequency. The remaining entities are given a "closeness measure" which is based on physical location. The "closeness measure" value of each entity is then compared to a specific distance and if the ratio of the former to the latter is greater than one, then the entity and target report are assumed to be the same.

If the target report is associated to more than one entity, a check will be made to see if the entities should be merged. A check is made into each of the candidate entities history files and then an evaluation is made as to whether to combine the entities or not. If the entities are combined, a new ID is given to the merged entities and the old entities are deleted from the data base.

For MTI associations, candidates are first screened by area of interest (AOI). The area of interest is the maximum radius possible given the maximum speed of the group and the time lapsed since the last group report. The remaining candidates are then assigned a MOA which is based on physical location. If the time lapse from the last group report to the current target report is large, then the MOA is calculated based on trafficability. The candidate groups that are remaining are then sorted according to whether they have a strong or weak association to the target report.

For C^3I identification and Imaging sensor reports, the group summary file is searched for groups whose records are closest to the time of the target report. These groups are then screened based on area of interest. Those groups which pass the AOI test are assigned an MOA which is based on physical location. Using predetermined thresholds, the group is given a strong or weak association to the target report based on its MOA value. If a target is associated highly with more than one group, then the history file of each group is checked to see if the groups should be merged. If the groups are merged then the newly formed group is given a new ID and the old groups are deleted.

For entity to group associations, the radio and radar detection reports are checked to see if they correspond with an entity that was previously associated with a group. If a link does exist between the entity and a group then the groups in the data base are screened according to physical location. The MOA is calculated for all groups that pass the screening test. The calculation of the MOA is based on the probability of the entity being associated with the group given the location of the entity. Based on the value of the MOA the entity to group association is given a confidence level. A check is then made into the histories of the entity and group to see if they should be associated together. Those that pass the history check and have a high confidence level are associated together.

WIDE AREA SURVEILLANCE

Knowledge of the level and type of activity across the battlefield is an essential asset when deciding where limited personnel and resources should be concentrated for intelligence collection. Such information would eliminate waste and speed up the identification process of units in regions of high activity. Wide Area Surveillance (WAS) utilizes the sensor reports to build a surveillance map divided into 5Km x 5Km grid cells over the whole cartographic area. Each grid cell indicates the level of activity overall and the level of activity for each sensor type by using a color coded scheme with each color representing a different threshold set by the user.

In determining the activity level of each sensor in the grid cells, the Wide Area Surveillance function counts the number of target reports for each sensor type per grid cell within two separate time periods. The time periods are divided into a short one of five minutes and a long one of an hour except for MTI target reports where surveillance data is already in a surveillance map format so the short interval is already completed. When an end to either time interval occurs, the finished surveillance map is stored and the new data is displayed.

MILITARY UNIT ANALYSIS

The limitation of resources imposed upon a tactical battlefield decision maker makes essential the identification and prioritisation of potential targets. Providing the identification capability within the ASE Element is the Military Unit Analysis (MUA) function. The military units can be identified from the correlated sensor and intelligence data by aggregating the groups and entities into larger units and then templating the larger untis' characteristics with characteristics of known units. The Military Unit Analysis function takes the groups and entities and aggregates them into battalions and the battalions into regiments and then identifies these units by their characteristics. The battalion was chosen as the basic military unit because, in non-nuclear conditions, the companies

in a battalion and the vehicles in a company are both spaced 25 to 50 meters apart. This makes it difficult to distinguish from separate companies in a battalion.

MUA aggregates all of the entities and groups from the correlated data base into higher level units. This aggregation algorithm builds higher level units by testing candidate groups to see if they fall within the expected length of the unit currently being built. Once all of the higher level units have been formed, a characteristics vector, which is the combined characteristics of all the elements in the unit is created. This characteristic vector is compared against known units and an attempt is made to identify the unit type and associate with it a confidence level. After the type of the unit has been distinguished, the element IDs of the candidate unit are compared with the element IDs of units already in the data base and if over one-half of the IDs match, then the data base is updated, otherwise a new unit is established in the data base.

SPECIAL TARGET ANALYSIS

An asset to any fighting unit is the ability to disrupt the enemy's command and control. To do this, information about the networks between units is required. Such information is supplied to the user by utilizing entity reports of the correlated data base. From these reports the Special Target Analysis (STA) function can form simplex nets, duplex nets and also identify the nodes and simplex nets by type.

In processing the reports, the Special Target Analysis function creates an entity block if the report incoming is the first one for that emitter. The description of the emitter is updated if the report is the second or greater. The emitter report is then processed further.

If the emitter is a radar, it is first templated to already existing nodes on the basis of co-location. Each node type must contain the radar type, and the node must not have its full complement or the emitter will not be associated to the node. If the emitter cannot be added to an existing node, then a new node is created utilizing unclustered radars and applying the templating process to them. An attempt is made to form additional air defense unit command elements where initial identification was ambiguous. This is done by templating and using additional doctrinal and deployment constraints. If the emitter cannot be associated with a node, then it is put in the unclustered emitter file.

If the emitter is a radio then it can be of two types; simplex or duplex. A simplex radio operates on a single frequency while a duplex radio operates on multiple frequencies. If the candidate emitter is a simplex radio, the function tries to find a simplex net operating at the same frequency and modulation as the emitter. The emitter is then added to a node on the basis of co-location and the fact that no other simplex radio at the node can have the same frequency. If the emitter cannot be added to a node or net then a new node or net is created utilizing unclustered entities. Whenever a simplex net has three or more members it is templated to find its type. Duplex radios are attempted to be added to existing duplex nets or nodes in the same manner as the simplex radios and the unclustered duplex radios are processed to form new nets or nodes. The nodes that are generated are templated to establish their type and any emitter that cannot be associated with a node is put in the unclustered emitter file.

Supernodes are formed from the fusion of radar, simplex radio, and duplex radio portions of a node. Once supernodes have been created or updated by the incoming emitter report they are templated to find their type and identification.

AUTO THREAT ANALYSIS

The Auto Threat Analysis function determines if any air defense unit (ADU) poses a threat to any planned friendly missions. If a threat does occur, a report is issued to the user indicating the threatened mission, the threatening ADU(s) and the legs of the mission that are threatened.

At the start up of the ASE Element and for each mission that is subsequently added, a check is made against every ADU and its coverage envelope. The coverage envelop or threat circle is assumed to be a cylinder centered at the ADU's location with the radius equal to the maximum range of the ADU's missile and the height equal to the maximum effective altitude of the missile. Both the radius and height of the threat circle are determined without regard to the terrain. Also, after a delta time of t, where t is determined beforehand, the STA File is searched for all known ADUs. If there is a new ADU, its characteristics (speed, location, type, and id) are added to the ADU Table of the Auto Threat Analysis function. The new ADU is then checked against all missions in the Threat Table to determine if a threat exists. All the ADUs that were previously recorded in the STA File are compared to their coordinates in the ADU Table and if there is any significant movement of the ADU, it is checked against all the missions in the Threat Table to determine if a threat exists and the ADU's new location is recorded into the ADU Table. Any threats as determined by the Auto Threat Analysis function are sent to the C^3I subsystem indicating mission, threatened legs, and threatening ADUs. This data is then displayed on a Cathode Ray Tube (CRT) screen.

DYNAMIC SITUATION ASSESSMENT

The user may select certain units as being of high priority and wish to follow the development of those units. But data is available on these targets only as long as the sensors can "see" them. Once the sensors lose a target due to shadowing or terrain masking, the user must expend valuable time recalculating all of the possible unit positions for that target. The Dynamic Situation Assessment (DSA) function of the ASE Element eliminates the problem of manual searching for a target once it is lost to shadowing and even identifies those targets that are a high priority.

The Dynamic Situation Assessment function first searches the Dynamic Order of Battle (DYOB) and STA Data Bases to identify targets that are to be considered high priority. When a high priority

target is found its type, ID, and location are saved for later use by the function. For every high priority target at an intersection, the position of the target at the next intersection is projected. The projected path is then checked to see if there will be any sensor loss due to shadowing. If some loss is found, the location of the loss and the sensor type are sent to the task sensor function. This loss information is then used to task the sensor to "look" at the projected exit points of the shadowed area at a time when the target is expected to be there. In this manner, the sensors keep a continuous watch on the high priority targets as identified by the user and the location of the targets is always known.

CONCLUSION

All of the functions of the ASE Element interact with monitor control functions which allow all data generated to be displayed graphically. This data is represented by varying symbols and colors and is overlayed on a digitized cartographic data base. The resulting "pictures" give the user an up-to-date graphical representation of the battlefield. The graphic displays, through the use of a man-machine interface function, allow the user to bring up specific statistics on the exact coordinates, speed, frequency, and etc. of any target in the data bases. This knowledge helps the user in deciding the planning, allocation and deployment of resources within his area of interest.

The ASE Element has been implemented on a VAX 11/785 utilizing FORTRAN as the programming language. All graphics are displayed on the RAMTEK graphics display monitor. Command inputs are made through the RAMTEK display system also. All textual data is displayed on Digital Equipment Corporation's VT-100 series terminals.

Utilizing the ASE Element within the ASE Testbed allows a more realistic evaluation of the functions utilized in the identification of battlefield targets. The modular approach in the design also allows the substitution of Testbed elements or ASE Element functions to test a variety of sources and functions. Planned upgrades and additions to the Testbed will expand the capabilities of the Testbed and provide an even more realistic test environment. Realistic test environments expedite the development of concepts and techniques that provide the user with the information that is required in the most efficient manner possible.

REFERENCES

Allen, Steven D., et al., PAR Technology Corp., Advanced Sensor Exploitation (ASE) Implementation Final Technical Report, May 1983, RADC-TR-82-334, Vol. I.

DISCUSSION

M.L. Busbridge, UK
What database are you using for your line of sight terrain obscuration?

J. Antonik
The database used is the US Defense Mapping Agency's Digital Terrain Elevation D-tabase (DTED). The level of the data is DTED Level III.

R. Cowderoy, UK
How much of the system has been constructed and how is the system being demonstrated?

J. Antonik
All of the functions and capabilities discussed in this paper have been constructed and implemented. The system is being demonstrated at RADC on a VAX 11/785 utilizing a RAMTEK graphics system. Graphic symbols (military units and such) are overlayed on a digitized cartographic database of the area of interest.